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Economics Letters 89 (2005) 48–54

economics letters

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# Stock market crashes and dynamics of aftershocks

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Received 6 April 2004; received in revised form 13 January 2005; accepted 11 May 2005
Available online 8 August 2005

**Abstract**

We begin with the intuitive observation that short-term business-as-usual process and bubble rising looks like an accelerated energy before an earthquake. In such a framework, the aftershocks resemble the correction process of the stock market. We investigate the statistical properties of stock returns in the financial markets just after a major market crash. It is found that the aftershocks obey the well-known Gutenberg–Richter simple rule in geophysics. Our empirical observations show that the statistical properties of aftershocks sequences in the crashes of late '90s and early '00s are essentially different from the ones observed a decade earlier.
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*Keywords:* Financial crashes; Energy; Acceleration; Aftershocks

*JEL classification:* G100; G150; F370

## 1. Introduction

A common feature in time series of financial markets is the existence of fat tailed price/returns distributions in the short term and the existence of crashes in the long term (Campbell et al., 1997; Mantegna and Stanley, 1998). Moreover, this asymmetry observed in the behaviour of valleys and peaks, and, in particular, with the existence of flat valleys and sharp peaks was studied by Roechner and Sornette (1998). They suggest that crashes might be outliers rather than fat tails of short-term

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doi:10.1016/j.econlet.2005.05.032

business-as-usual market movements (Johansen and Sornette, 1998a; Johansen et al., 2000; Focardi et al., 2002).

Most of the recent theoretical literature is consistent with the above statistical phenomenon. The "rational panic model" of Barlevy and Veronesi (2003) shows that uninformed traders can precipitate a price crash because as prices decline, they surmise that informed traders received negative information, which leads them to reduce their demand for assets and drive the prices of stocks even lower. In the "hedging model" of Gennotte and Leland (1990), the exogenous portfolio insurers precipitate price declines by selling stocks when prices fall, thus magnifying small price changes into large, discontinuous jumps. Moreover, a series of other models explain crashes as episodes in which agents learn about some underlying fundamental they were previously uncertain about and react to this information (Kraus and Smith, 1989; Lee, 1998; Zeira, 1999; Hong and Stein, 2003). Also, Madrigal and Scheinkman (1997) generate a price crash that is due to strategic manipulation by a fully informed market maker who finds it optimal to coarsen the information set for potential buyers in bad states of the world, causing a discrete jump down in prices when bad outcomes occur. Recently, market crashes are modelled in a framework, which represents stock market behaviour as the interaction of self-organising processes (Focardi et al., 2002; Cont and Bouchaud, 2000; Stauffer and Sornette, 1999) and describes it as a dynamical out-of-equilibrium system (and Johansen and Sornette, 1998b; Levy et al., 1995).

In this paper, we start from the intuitive observation that short-term business-as-usual process and bubble rising looks like an accelerated energy before an earthquake. In such a framework, the aftershocks look like the correction process of the market. We investigate the statistical properties of stock returns in a financial market just after a major market crash. The property of "aftershocks" (i.e., catastrophes of smaller scales) after a main shock is studied by analysing a set of time series data for emerging and developed markets. It is found that the aftershocks obey the well-known Gutenberg–Richter simple rule in geophysics.

## 2. Modelling the aftershocks

The purpose of our attempt to model the dynamics of market index returns, just after a crash is to look for a statistical regularity with respect to the number of times the absolute value of index return exceeds a given threshold value. Gutenberg and Richter (1956) introduced a simple relationship between the number and the magnitude of aftershocks. More specifically, the number of earthquakes of magnitude $m$ or greater, $v(m)$, is given by

$$\log v(m) = \alpha - b \cdot m \tag{1}$$

where $\alpha$ and $b$ are two constants, and their economic notion will be discussed shortly. Firstly, we define the dates of two major shocks (earthquakes) in each country during the sample period as days of crashes. At a second stage, we define aftershocks as the daily absolute returns, which are greater than one standard deviation ($\sigma$) immediately (100 next days) after the major shock (Selcuk, 2004):

$$r_{i,t} = \log\left(p_{i,t}/p_{i,t-1}\right) = \log p_{i,t} - \log p_{i,t-1} > 1\sigma_r \tag{2}$$

where $p$ is the price of the index and $r$ is the return.

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